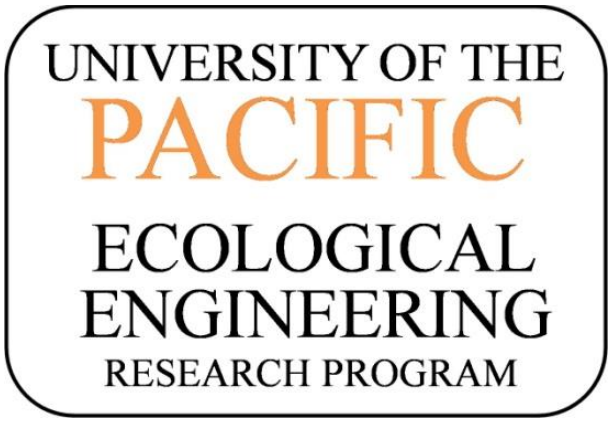

Analysis of the Gowdy Output Results from the SJR-WARMF 2012 Model

Report 4.8.2

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List of Acronyms

CALFED	Collaboration Among State and Federal Agencies to Improve California's Water Supply
Catch.	Catchment
CBOD	Carbonaceous Biochemical Oxygen Demand
CCID	Central California Irrigation District
chl	Chlorophyll-a
CUWA	California Urban Water Agencies
CVRWQCB	California Central Valley Regional Water Quality Control Board
CV-SALTS	Central Valley Salinity Alternatives for Long-Term Sustainability
Diff.	Difference
DMC	Delta Mendota Canal
DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon
DWSC	Deep Water Ship Channel
EERP	Ecological Engineering Research Program
ID	Irrigation District (when not used to refer to a model element number)
kg	Kilograms
kg chl	Kilograms as Chlorophyll-a
MODFLOW	Modular Finite-Difference Flow Model
MWD	Metropolitan Water District of Southern California
NO3-N	Dissolved Nitrate Plus Nitrite as Nitrogen
PO4-P	Dissolved Orthophosphate as Phosphorus
SJR	San Joaquin River
TAN	Total Ammonia Plus Ammonium Nitrogen
TDS	Total Dissolved Solids
TID	Turlock Irrigation District
TMDL	Total Maximum Daily Load
TP	Total Phosphorus
USBR	United States Bureau of Reclamation
WARMF	Watershed Analysis Risk Management Framework
WD	Water District
WQCF	Water Quality Control Facility

Introduction

The Watershed Analysis Risk Management Framework model of the upper San Joaquin River (SJR-WARMF) is a mechanistic watershed model developed and maintained by Systech Engineering that simulates flow and water quality in the non-tidal upper San Joaquin River (SJR) watershed downstream of Friant Dam and upstream of Old River and passes water quality outputs as input for the Link-Node model, which simulates the downstream tidal estuary (Chen and Tsai 2002). Both models have been used to analyze oxygen-consuming substances contributing to low dissolved oxygen (DO) events in the Stockton Deep Water Ship Channel (DWSC) in support of total maximum daily load (TMDL) efforts. The model version SJR-WARMF 2008 simulates the SJR from a point upstream of Lander Avenue to Old River, utilizing 32 catchments for simulating precipitation, land application, and runoff (Herr, Chen, and Werkhoven 2008). The model included part of the western tributaries and utilized boundary inflow files at the extents of the model domain. SJR-WARMF 2008 was updated to SJR-WARMF 2012 by expanding the model domain to include all of the western tributaries and the SJR downstream of Friant Dam; expanding land use, irrigation, and land application modeling; updating catchment delineations; updating river segments; and making improvements to the model engine and interface (Systech 2012).

In this report, we tested the SJR-WARMF 2012 model for used in identifying source of oxygen demand in the SJR basin. The SJR-WARMF 2012 model was used to calculate flow and load contributions from sources between Lander Ave and Vernalis. Loads were calculated using a methodology referred to as the Gowdy Output which tracks loads from individual watersheds by including a calculation on instream transformation as accounted for by the mechanistic model. Here, the Gowdy Output feature was used with SJR-WARMF 2012 to determine sources of oxygen-consuming substances contributing to the DO impairment in the Stockton DWSC and establish TMDLs. The objectives of this study were to use SJR-WARMF 2012 with the Gowdy Output to determine the major contributors to the DO impairment in the Stockton DWSC and to develop data sets that are supportive of water quality management decisions.

Materials and Methods

SJR-WARMF 2012 Model

The SJR-WARMF 2012 model, as adapted to the SJR, consists of a network of linked rivers, catchments, and reservoirs describing the upper SJR watershed between the Millerton Lake Tailwater (River ID 56) and Old River (River ID 319). Water quality output at Old River is utilized as input by the Link-Node model, which simulates the tidal estuary region of the SJR between Old River and Rindge Tract. Although the Link-Node model domain can be viewed in SJR-WARMF, inputs must be edited outside of SJR-WARMF and only time series output is available (Herr, Chen, and Werkhoven 2008). Analysis between observed and simulated water quality data was performed at the Vernalis water quality and flow monitoring station (River ID 184) since it is the furthest point downstream within the SJR-WARMF 2012 model domain that is unaffected by tidal flow. Also, the Vernalis monitoring station has been used extensively in other studies and a large quantity of water quality data has been collected at this site (DWR 2013; San Joaquin River Group Authority 2013; USBR 2012b).

SJR-WARMF 2008 was incrementally updated to SJR-WARMF 2012 through a series of independent projects (Figure 1). Each model update included updates to land use categories, land application rates, meteorology data, soil parameters, and irrigation rates. The first version of the SJR-WARMF model of the upper SJR watershed was created in 2008 in the upstream study of the SJR under CALFED. Catchments primarily along the main stem of the river were modeled; boundary inflow files consisting of observed water quality data were used to define inputs to individual tributaries (Herr, Chen, and van Werkhoven 2008). In 2008, the model domain was extended to the SJR downstream of Friant Dam for the United States Bureau of Reclamation (USBR) so that the SJR watershed upstream of Bear Creek could be simulated separately (Systech 2011). During the Central Valley Salinity Alternatives for Long-Term Sustainability (CV-SALTS) Salt and Nitrate Pilot Implementation Study in 2010, the eastside catchments were updated based on drainage boundaries and modular finite-difference flow model (MODFLOW) groundwater cells, which were used to create point source files representing groundwater pumping for SJR-WARMF to use (Larry Walker Associates et al. 2010). In a similar project, the Westside Salt Assessment by the USBR, the western domain of the SJR-WARMF model was updated in 2010 and expanded to include headwater catchments that contribute to winter runoff in the western streams and additional groundwater data was included based on observed measurements and streamflow-based estimates (USBR 2012a; USBR 2012c; Systech 2011). In the following project by the California Urban Water Agencies (CUWA) and the Central Valley Drinking Water Policy Work Group, additional updates to model coefficients to catchments and river segments between the SJR at Old River and Lander Avenue were performed (Systech 2011). The boundary inflow file for the SJR at Lander Avenue was removed and river bed scour and clay and silt particle settling velocity rates were modified to calibrate SJR-WARMF for flow simulation at Lander Avenue and at Vernalis to forecast flow and turbidity for the 2012 water year for the Metropolitan Water District of Southern California's (MWD) plant operators at the Banks Pumping Plant (Systech 2012). The latest documented updates to SJR-WARMF were from the Focused Agricultural Drainage Study for the SJR DO TMDL project, where Systech and EERP improved the catchment delineations and model coefficients for the Orestimba Creek subwatershed to gain a better understanding of how changes to agricultural land management practices affect nutrients in Orestimba Creek (Systech 2013).

Gowdy Output

The Gowdy Output is a post-processing routine based on a spreadsheet developed by Mark Gowdy of the California Central Valley Regional Water Quality Control Board (CVRWQCB) that calculates flow and load contributions at upstream ends of river segments where intakes or discharges from tributaries, catchment runoff, point sources, and/or diversions occur. The source contributions were calculated by representing mass from each river segment and input as a percentage of the total load, accounting for in-stream processes without changing the percentages of each source, and rebalancing at each downstream river segment while including an adjustment factor for travel time (Herr, personal communication). In SJR-WARMF 2012, the mass load output is expressed as a cumulative daily load regardless of the time step used in the model simulation.

Model Simulation

Systech Engineering applied the Gowdy Output along the SJR from the site near Stevinson (River ID 752) to Vernalis for the SJR-ARMF 2012 baseline scenario that was run using a 6-hour time step for the time period from October 1, 2004 through September 30, 2012 and sent the exported data to the Ecological Engineering Research Program (EERP) for analysis (Figure 2). There are 59 source points between Stevinson and Vernalis, which includes 12 catchment discharge points, 23 river discharge points, and 24 diversions (Table A, Figure C). The Gowdy Output results were collected for flow, dissolved nitrate plus nitrite as nitrogen (NO_3-N), total ammonia plus ammonium nitrogen (TAN), total nitrogen (TN), dissolved orthophosphate as phosphorus (PO_4-P), total phosphorus (TP), dissolved organic carbon (DOC), carbonaceous biochemical oxygen demand (CBOD), total dissolved solids (TDS), and total phytoplankton as chlorophyll-a (chl).

Comparison of the WARMF 2012 Gowdy Output with the WARMF 2008 Load Removal Analysis

The mass loads calculated using the Gowdy Output were compared with results from the SJR-WARMF 2008 load removal analysis conducted by Jue et al. (2013) where load contributions at Vernalis were analyzed by running model simulations where mass loads from the tributaries were sequentially removed by setting boundary inflow constituent concentrations to zero. Since the load removal analysis and the Gowdy Output data were conducted using different time frames, the total mass at Vernalis for each tributary removal scenario was re-calculated for the time period January 1, 2005 through September 30, 2007—the time period where the studies overlap. Then, the mass load at Vernalis resulting from each of the removed tributaries was calculated by subtracting the mass load at Vernalis contributed by the removal of the tributary from the total mass load at Vernalis calculated using the baseline scenario. The mass load for each tributary in the Gowdy Output analysis was calculated by summing the mass loads for each day from January 1, 2005 through September 30, 2007 and multiplying by the time step of 6-hours, with unit conversions performed as needed. Missing data points were excluded from the summation. The following major tributaries were selected for comparison of the results obtained from the SJR-WARMF 2008 load removal analysis and the SJR-WARMF 2012 Gowdy Output: Tuolumne River, Stanislaus River, SJR at Lander Ave., Merced River, Salt Slough, Hospital Creek, Ingram Creek, Mud Slough, Los Banos Creek, Turlock Irrigation District (TID) Lateral 3 (Westport) Drain, TID Harding Drain, Del Puerto Creek, and Orestimba Creek. The mass loads from Hospital and Ingram Creek in the SJR-WARMF 2008 model were added together to allow comparison with the Gowdy Output, since these tributaries were modeled as converging before discharging into the SJR. Likewise, the mass loads from Los Banos Creek were also added together.

Results and Discussion

Mass Load Sources in the San Joaquin River

Sources of flow and water quality constituent mass loads at Vernalis, originating from upstream sources in the SJR, are listed in Table 2 through 1. In these tables sources have been sorted

based on contribution. Cumulative percentages that are shown in each table account for the percentage of all of the simulated sources contributing to the simulated mass loads at Vernalis. The sum of the mass loads adds up to a total percentage higher than 100% due to the reductions in mass loads from diversions. Based on the simulation results from the SJR-WARMF-2012 model, the Tuolumne River, Stanislaus River, SJR at Lander Avenue, and Merced River at Stevinson were among the top five sources for flow and water quality mass loads. The combination of these four sources accounts for 87% of the water volume, 65% of the NO_3-N, 57% of the TAN, 62% of the TN, 64% of the PO_4-P, 51% of the TP, 71% of the DOC, 83% of the CBOD, 35% of the TDS, and 93% of the total phytoplankton (chl) mass loads observed at Vernalis. The SJR at Lander Ave. is the highest simulated contributor of total phytoplankton (chl) and the second highest simulated contributor of CBOD, suggesting that the SJR upstream of Lander Ave. is a major contributor to the DO deficit in the Stockton DWSC. The Tuolumne River, while being the highest simulated contributor of CBOD and the third highest simulated contributor of total phytoplankton (chl), contributes only 11% of the total phytoplankton (chl) mass load at Vernalis while contributing 29% of the CBOD at Vernalis and 21% of the DOC mass loads at Vernalis.

According to the WARMF 2012 model output, the four next largest simulated CBOD sources are Los Banos Creek, Salt Slough, the Modesto Water Quality Control Facility (WQCF) discharge, and Newman Wasteway. These sources account for the remaining 17% of the total CBOD mass when the Tuolumne River, Stanislaus River, San Joaquin River at Lander Avenue, and Merced River at Stevinson are included. The sum of the CBOD mass loads from the remaining sources is 4%, which is approximately equivalent to the sum of the diversions. According to the model, the largest identifiable simulated source of CBOD was the Modesto WQCF, which contributed 3% of the total CBOD mass load at Vernalis; the remaining sources each contributed 1% or less of the total CBOD mass load at Vernalis. Additional analysis is recommended to investigate CBOD sources within each of the major contributing tributaries.

A comparison of the WARMF 2012 Gowdy Output mass loads and the mass loads calculated from the tributary inflow files at the model domain boundaries for Stanislaus, Tuolumne, and Merced Rivers is shown in Table 12. The loads from the boundary inflow are equal to 83% of the total mass load at Vernalis for NO_3-N, TAN, PO_4-N, DOC, and CBOD. Due to the way that the WARMF 2012 model interfaces with the Link-Node model, it was not possible to produce the Gowdy Output along the San Joaquin River from Stevinson to the Stockton DWSC. This would be more desirable so in-stream processes between Vernalis and the Stockton DWSC can be accounted for.

Comparison with the WARMF 2008 Model

Mass load distributions obtained from the WARMF 2012 Gowdy Output were compared with the mass load contributions obtained from the WARMF 2008 load removal analysis (Table 13 and 14). Each mass was expressed as a percentage of the total mass at Vernalis. By comparing the percent contributions of each tributary, it is possible to determine whether the tributaries were modeled consistently between the two models. Additionally, the magnitude of the mass loads between the two models were compared by subtracting the WARMF 2012 model mass

loads from the WARMF 2008 model mass loads and calculating the percent increase or decrease with respect to the WARMF 2008 model version.

There are similar trends in the percentage of total mass between the two models for NO_3-N, DOC, CBOD, and TDS, but not for the remaining water quality constituents. In addition, there were large differences in the percentage of total mass not accounted for by the major tributaries between the two models for TAN, PO_4-P, and TP and there are large percent differences between the mass loads simulated for the individual tributaries in the WARMF 2012 and 2008 versions, with values differing by as much as 2,722%. The WARMF 2008 largely uses measured data for inputs and is believed to be a more accurate model. These results suggest that individual watersheds are not well calibrated in the WARMF-2012 model. This conclusion is also supported by other analyses, which also indicate need for better characterization of subwatersheds and improvements to model calibration of individual tributaries, so that the simulation results are more reliable for identifying significant sources of nutrient loads (see appendix 5.2.2).

Recommendations

The results of the Gowdy Output provide a first approximation for determining which tributaries and other sources along the SJR may be responsible for the DO impairment in the Stockton DWSC. Additional Gowdy Output analyses with longer time periods into individual tributaries, along with an expansion of the model domain to better characterize the eastside tributaries, are recommended to identify major contributors to mass loads at Vernalis. Once sources are identified, further studies can be conducted to get a sense of whether the Gowdy Output provided an accurate estimate of each source's responsibility for the DO deficit in the Stockton DWSC. This may be useful for deciding where to allocate resources for improving the model's characterization of individual tributaries and for developing capabilities to conduct Gowdy Output analyses from Vernalis to the Stockton DWSC. These efforts can be conducted until the accuracy and precision desired for decision-making is achieved.

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Table 1. Tributaries, catchments, and diversions located along the San Joaquin River between Stevinson and Vernalis contributing to flow and mass loads at Vernalis. Sources are listed from upstream to downstream locations with their corresponding river IDs, catchment IDs, and diversion files utilized in the WARMF 2012 model. The river ID for the point of discharge or intake is also shown to identify the segment of the San Joaquin River where the discharge or intake occurs. See Figure C for a map of river points.

River Point Number	Source	Type	River ID	Catch. ID	Diversion File	Discharge/ Intake Point ID
1	Subcatchment 836	Catchment		836		752
2	San Joaquin at Lander Ave.	River	753			752
3	Riparian 836	Diversion			Riparian 836.FLO	752
4	Riparian diversion to catchment 849	Diversion			Riparian 849.FLO	750
5	Salt Slough at San Joaquin River	River	249			749
6	Subcatchment 852	Catchment		852		747
7	Riparian 852	Diversion			Riparian 852.FLO	747
8	Riparian 854	Diversion			Riparian 854.FLO	744
9	Subcatchment 854	Catchment		854		742
10	Los Banos Creek at San Joaquin R.	River	384			742
11	Newman Wasteway	River	259			742
12	Riparian diversion to catchment 843	Diversion			Riparian 843.FLO	742
13	Merced River at Stevinson	River	107			739
14	Subcatchment 955	Catchment		955		736
15	Subcatchment 961	Catchment		961		736
16	CCID North/ SJR Drainage S	Catchment		801		736
17	Riparian 961	Diversion			Riparian 961.FLO	736
18	Riparian diversions to catchment 955	Diversion			Riparian 955.FLO	736
19	TID Lateral 6 & 7 Spill	River	198			733
20	Crows Landing-WS Div7	Diversion			Crows Landing SJR.FLO	732
21	Orestimba Creek near Crows Landing	River	165			731
22	Moran Drain	River	199			731
23	Spanish Land Grant Drain	River	196			731
24	Marshall Road Drain	River	201			731
25	TID Harding Drain	River	202			728
26	Riparian 960	Diversion			Riparian 960.FLO	728
27	TID Lateral 5 (Carpenter) Drain	River	203			727
28	Subcatchment 960	Catchment		960		725
29	Salado Creek	River	344			723
30	San Joaquin diversions to Patterson WD	Diversion			Patterson WD SJR.FLO	723
31	Subcatchment 840	Catchment		840		720
32	Modesto WQCF Discharge	River	211			720
33	Riparian 840	Diversion			Riparian 840.FLO	720
34	TID Lateral 3 (Westport) Drain	River	204			718
35	Del Puerto Creek	River	339			717
36	San Joaquin diversions to Patterson WD2	Diversion			Patterson WD SJR.FLO	717
37	PATTERSON WD deliveries from DMC	Diversion			Patterson wd dmc.flo	717
38	TID Lateral 2 Drain	River	205			715
39	Subcatchment 832	Catchment		832		714
40	Westley Wasteway	River	206			714
41	San Joaquin diversions to W. Stanislaus ID	Diversion			W Stanislaus ID SJR.FLO	714
42	Riparian 832	Diversion			Riparian 832.FLO	713
43	Riparian diversions to Catchment 188	Diversion			Riparian 188.FLO	710
44	Riparian diversions to catchments 188 & 200	Diversion			Riparian 188 & 200.FLO	710

(continued on the next page)

(Table 1 continued from the previous page)

River Point Number	Source	Type	River ID	Catch. ID	Diversion File	Discharge/ Intake Point ID
45	Tuolumne River at SJR	River	122			708
46	MID Lateral 5 Spill	River	207			708
47	MID Lateral 4 Spill	River	208			706
48	Riparian 291	Diversion			Riparian 291.FLO	706
49	Hospital / Ingram Creek	River	304			705
50	El Solyo WD Pump Station	Diversion			El Solyo WD SJR.FLO	704
51	Subcatchment 188	Catchment		188		703
52	Subcatchment 291	Catchment		291		703
53	San Joaquin diversions to W. Stanislaus ID3	Diversion			W Stanislaus ID SJR.FLO	703
54	W STANISLAUS ID deliveries from DMC	Diversion			W stanislaus id dmc.flo	703
55	El Solyo WD Pump Station4	Diversion			El Solyo WD SJR.FLO	703
56	Riparian diversions to catchment 188, part 2	Diversion			Riparian 224.FLO	702
57	Stanislaus River at SJR	River	157			701
58	Subcatchment 264	Catchment		264		184
59	Riparian 264	Diversion			Riparian 264.FLO	184

Table 2. Upstream sources of water volume at Vernalis sorted by water volume from January 1, 2005 through September 30, 2007.

River Point Number	Location	Volume ($L \times 10^6$)	% of Total Mass	Cumulative %
45	Tuolumne River at SJR	5,028,717	32%	32%
2	San Joaquin at Lander Ave.	3,274,092	21%	52%
57	Stanislaus River at SJR	3,133,887	20%	72%
13	Merced River at Stevinson	2,423,604	15%	87%
10	Los Banos Creek at San Joaquin R.	414,389	3%	90%
5	Salt Slough at San Joaquin River	357,919	2%	92%
38	TID Lateral 2 Drain	305,602	2%	94%
49	Hospital / Ingram Creek	178,095	1%	95%
19	TID Lateral 6 & 7 Spill	151,295	1%	96%
11	Newman Wasteway	139,680	1%	97%
34	TID Lateral 3 (Westport) Drain	117,096	1%	98%
21	Orestimba Creek near Crows Landing	110,212	1%	98%
29	Salado Creek	97,853	1%	99%
25	TID Harding Drain	89,831	1%	99%
27	TID Lateral 5 (Carpenter) Drain	88,893	1%	100%
35	Del Puerto Creek	76,565	0.5%	100%
46	MID Lateral 5 Spill	76,203	0.5%	101%
47	MID Lateral 4 Spill	48,081	0.3%	101%
32	Modesto WQCF Discharge	45,497	0.3%	102%
31	Subcatchment 840	44,235	0.3%	102%
23	Spanish Land Grant Drain	41,326	0.3%	102%
1	Subcatchment 836	41,105	0.3%	102%
51	Subcatchment 188	31,615	0.2%	103%
39	Subcatchment 832	20,940	0.1%	103%
16	CCID North/ SJR Drainage S	19,753	0.1%	103%
15	Subcatchment 961	18,614	0.1%	103%
52	Subcatchment 291	11,448	0.1%	103%
9	Subcatchment 854	10,327	0.1%	103%
6	Subcatchment 852	8,603	0.1%	103%
40	Westley Wasteway	7,025	0%	103%
14	Subcatchment 955	5,592	0%	103%
28	Subcatchment 960	3,901	0%	103%
58	Subcatchment 264	962	0%	103%
36	San Joaquin diversions to Patterson WD	16.2	0%	103%
55	El Solyo WD Pump Station	15.3	0%	103%
54	W STANISLAUS ID deliveries from DMC	10.7	0%	103%
53	San Joaquin diversions to W. Stanislaus ID	4.33	0%	103%
37	PATTERSON WD deliveries from DMC	2.32	0%	103%
24	Marshall Road Drain	0	0%	103%
22	Moran Drain	0	0%	103%
59	Riparian 264	-1,503	0%	103%
20	Crows Landing-WS Div7	-3,380	0%	103%
12	Riparian diversion to catchment 843	-3,561	0%	103%
4	Riparian diversion to catchment 849	-5,230	0%	103%
7	Riparian 852	-5,416	0%	103%
33	Riparian 840	-7,121	0%	103%
8	Riparian 854	-9,644	-0.1%	103%
43	Riparian diversions to Catchment 188	-15,720	-0.1%	103%
18	Riparian diversions to catchment 955	-16,361	-0.1%	103%
48	Riparian 291	-18,768	-0.1%	103%
56	Riparian diversions to catchment 188, part 2	-21,333	-0.1%	102%

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(Table 2 continued from the previous page)

River Point Number	Location	Volume ($L \times 10^6$)	% of Total Mass	Cumulative %
26	Riparian 960	-22,143	-0.1%	102%
42	Riparian 832	-25,490	-0.2%	102%
3	Riparian 836	-30,984	-0.2%	102%
17	Riparian 961	-34,987	-0.2%	102%
44	Riparian diversions to catchments 188 & 200	-37,900	-0.2%	102%
41	San Joaquin diversions to W. Stanislaus ID	-42,003	-0.3%	101%
50	El Solyo WD Pump Station	-80,381	-1%	101%
30	San Joaquin diversions to Patterson WD	-123,701	-1%	100%
	Total	**15,917,383**		

Table 3. Upstream sources of dissolved nitrate plus nitrite as nitrogen NO_3-N at Vernalis sorted by NO_3-N mass load from January 1, 2005 through September 30, 2007.

River Point Number	Model Source Name	NO_3-N (kg)	% of Total Mass	Cumulative %
13	Merced River at Stevinson	1,959,143	25%	25%
45	Tuolumne River at SJR	1,855,412	24%	48%
57	Stanislaus River at SJR	692,127	9%	57%
2	San Joaquin at Lander Ave.	641,873	8%	65%
10	Los Banos Creek at San Joaquin R.	534,104	7%	72%
5	Salt Slough at San Joaquin River	356,982	5%	77%
32	Modesto WQCF Discharge	315,554	4%	81%
38	TID Lateral 2 Drain	280,650	4%	84%
19	TID Lateral 6 & 7 Spill	232,908	3%	87%
11	Newman Wasteway	198,642	3%	90%
31	Subcatchment 840	197,426	3%	92%
49	Hospital / Ingram Creek	181,828	2%	94%
27	TID Lateral 5 (Carpenter) Drain	145,280	2%	96%
34	TID Lateral 3 (Westport) Drain	139,833	2%	98%
1	Subcatchment 836	128,216	2%	100%
25	TID Harding Drain	124,210	2%	101%
23	Spanish Land Grant Drain	69,464	1%	102%
21	Orestimba Creek near Crows Landing	66,632	1%	103%
29	Salado Creek	63,995	1%	104%
16	CCID North/ SJR Drainage S	33,057	0.4%	104%
46	MID Lateral 5 Spill	32,382	0.4%	105%
9	Subcatchment 854	31,033	0.4%	105%
47	MID Lateral 4 Spill	30,073	0.4%	105%
51	Subcatchment 188	29,338	0.4%	106%
6	Subcatchment 852	27,460	0.3%	106%
39	Subcatchment 832	25,589	0.3%	106%
35	Del Puerto Creek	23,024	0.3%	107%
40	Westley Wasteway	12,753	0.2%	107%
15	Subcatchment 961	11,240	0.1%	107%
14	Subcatchment 955	3,376	0%	107%
52	Subcatchment 291	2,550	0%	107%
28	Subcatchment 960	2,273	0%	107%
58	Subcatchment 264	48.7	0%	107%
54	W STANISLAUS ID deliveries from DMC	30.3	0%	107%
36	San Joaquin diversions to Patterson WD	18.5	0%	107%
55	El Solyo WD Pump Station	14.2	0%	107%
37	PATTERSON WD deliveries from DMC	7.51	0%	107%
53	San Joaquin diversions to W. Stanislaus ID	4.38	0%	107%
22	Moran Drain	0	0%	107%
24	Marshall Road Drain	0	0%	107%
59	Riparian 264	-1,090	0%	107%
12	Riparian diversion to catchment 843	-2,730	0%	107%
7	Riparian 852	-4,038	-0.1%	107%
4	Riparian diversion to catchment 849	-4,099	-0.1%	107%
20	Crows Landing-WS Div7	-4,906	-0.1%	107%
8	Riparian 854	-7,000	-0.1%	107%
33	Riparian 840	-9,024	-0.1%	107%
43	Riparian diversions to Catchment 188	-16,797	-0.2%	106%
48	Riparian 291	-18,904	-0.2%	106%
56	Riparian diversions to catchment 188, part 2	-19,676	-0.2%	106%
3	Riparian 836	-22,375	-0.3%	106%

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(Table 3 continued from the previous page)

River Point Number	Model Source Name	NO_3-N (kg)	% of Total Mass	Cumulative %
18	Riparian diversions to catchment 955	-24,792	-0.3%	105%
42	Riparian 832	-29,477	-0.4%	105%
26	Riparian 960	-30,165	-0.4%	105%
44	Riparian diversions to catchments 188 & 200	-43,585	-1%	104%
41	San Joaquin diversions to W. Stanislaus ID	-49,330	-1%	103%
17	Riparian 961	-50,389	-1%	103%
50	El Solyo WD Pump Station	-74,932	-1%	102%
30	San Joaquin diversions to Patterson WD	-144,268	-2%	100%
	Total	**7,890,971**		

Table 4. Upstream sources of total ammonia plus ammonium nitrogen (TAN) at Vernalis sorted by TAN mass load from January 1, 2005 through September 30, 2007.

River Point Number	Model Source Name	TAN (kg)	% of Total Mass	Cumulative %
45	Tuolumne River at SJR	254,467	23%	23%
57	Stanislaus River at SJR	196,977	18%	42%
32	Modesto WQCF Discharge	119,240	11%	53%
13	Merced River at Stevinson	96,858	9%	62%
2	San Joaquin at Lander Ave.	65,834	6%	68%
49	Hospital / Ingram Creek	64,224	6%	74%
34	TID Lateral 3 (Westport) Drain	53,543	5%	78%
19	TID Lateral 6 & 7 Spill	51,661	5%	83%
27	TID Lateral 5 (Carpenter) Drain	47,538	4%	88%
25	TID Harding Drain	39,922	4%	91%
38	TID Lateral 2 Drain	32,835	3%	94%
47	MID Lateral 4 Spill	29,459	3%	97%
46	MID Lateral 5 Spill	29,002	3%	100%
29	Salado Creek	27,597	3%	102%
35	Del Puerto Creek	24,994	2%	105%
10	Los Banos Creek at San Joaquin R.	17,487	2%	106%
39	Subcatchment 832	12,545	1%	107%
1	Subcatchment 836	12,472	1%	108%
9	Subcatchment 854	11,936	1%	110%
5	Salt Slough at San Joaquin River	11,921	1%	111%
11	Newman Wasteway	10,778	1%	112%
51	Subcatchment 188	9,453	1%	113%
15	Subcatchment 961	5,397	0.5%	113%
6	Subcatchment 852	5,386	0.5%	114%
23	Spanish Land Grant Drain	4,634	0.4%	114%
31	Subcatchment 840	2,987	0.3%	114%
52	Subcatchment 291	1,899	0.2%	114%
40	Westley Wasteway	1,872	0.2%	115%
58	Subcatchment 264	1,643	0.2%	115%
16	CCID North/ SJR Drainage S	1,517	0.1%	115%
28	Subcatchment 960	1,221	0.1%	115%
21	Orestimba Creek near Crows Landing	1,034	0.1%	115%
14	Subcatchment 955	555	0.1%	115%
36	San Joaquin diversions to Patterson WD	7.00	0%	115%
55	El Solyo WD Pump Station	4.65	0%	115%
53	San Joaquin diversions to W. Stanislaus ID	1.87	0%	115%
54	W STANISLAUS ID deliveries from DMC	0.669	0%	115%
37	PATTERSON WD deliveries from DMC	0.136	0%	115%
22	Moran Drain	0	0%	115%
24	Marshall Road Drain	0	0%	115%
59	Riparian 264	-366	0%	115%
20	Crows Landing-WS Div7	-905	-0.1%	115%
12	Riparian diversion to catchment 843	-907	-0.1%	115%
7	Riparian 852	-1,172	-0.1%	115%
4	Riparian diversion to catchment 849	-1,259	-0.1%	115%
8	Riparian 854	-2,043	-0.2%	115%
18	Riparian diversions to catchment 955	-2,734	-0.3%	114%
33	Riparian 840	-2,929	-0.3%	114%
17	Riparian 961	-5,566	-1%	113%
48	Riparian 291	-5,928	-1%	113%
43	Riparian diversions to Catchment 188	-6,355	-1%	112%

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(Table 4 continued from the previous page)

River Point Number	Model Source Name	TAN (kg)	% of Total Mass	Cumulative %
3	Riparian 836	-6,572	-1%	112%
56	Riparian diversions to catchment 188, part 2	-6,742	-1%	111%
26	Riparian 960	-6,970	-1%	110%
42	Riparian 832	-10,993	-1%	109%
44	Riparian diversions to catchments 188 & 200	-15,051	-1%	108%
41	San Joaquin diversions to W. Stanislaus ID	-17,113	-2%	106%
50	El Solyo WD Pump Station	-24,500	-2%	104%
30	San Joaquin diversions to Patterson WD	-45,868	-4%	100%
	Total	**1,084,928**		

Table 5. Upstream sources of total nitrogen (TN) mass at Vernalis sorted by TN mass load from January 1, 2005 through September 30, 2007.

River Point Number	Model Source Name	TN (kg)	% of Total Mass	Cumulative %
45	Tuolumne River at SJR	3,161,356	19%	19%
13	Merced River at Stevinson	2,759,603	17%	36%
2	San Joaquin at Lander Ave.	2,515,338	15%	52%
57	Stanislaus River at SJR	1,561,827	10%	62%
10	Los Banos Creek at San Joaquin R.	1,033,915	6%	68%
5	Salt Slough at San Joaquin River	791,190	5%	73%
19	TID Lateral 6 & 7 Spill	664,616	4%	77%
32	Modesto WQCF Discharge	634,346	4%	81%
38	TID Lateral 2 Drain	446,464	3%	84%
27	TID Lateral 5 (Carpenter) Drain	396,043	2%	86%
25	TID Harding Drain	378,204	2%	88%
49	Hospital / Ingram Creek	365,709	2%	91%
34	TID Lateral 3 (Westport) Drain	351,841	2%	93%
31	Subcatchment 840	293,246	2%	95%
11	Newman Wasteway	290,192	2%	96%
1	Subcatchment 836	261,224	2%	98%
9	Subcatchment 854	194,441	1%	99%
29	Salado Creek	184,984	1%	100%
6	Subcatchment 852	138,623	1%	101%
46	MID Lateral 5 Spill	129,993	1%	102%
35	Del Puerto Creek	121,004	1%	103%
21	Orestimba Creek near Crows Landing	120,181	1%	103%
47	MID Lateral 4 Spill	108,877	1%	104%
23	Spanish Land Grant Drain	86,697	1%	105%
39	Subcatchment 832	77,984	0.5%	105%
51	Subcatchment 188	55,361	0.3%	105%
16	CCID North/ SJR Drainage S	45,358	0.3%	106%
15	Subcatchment 961	44,760	0.3%	106%
40	Westley Wasteway	18,791	0.1%	106%
52	Subcatchment 291	12,802	0.1%	106%
14	Subcatchment 955	9,999	0.1%	106%
28	Subcatchment 960	7,333	0.1%	106%
58	Subcatchment 264	2,318	0%	106%
36	San Joaquin diversions to Patterson WD	34.7	0%	106%
54	W STANISLAUS ID deliveries from DMC	33.3	0%	106%
55	El Solyo WD Pump Station	24.2	0%	106%
37	PATTERSON WD deliveries from DMC	8.06	0%	106%
53	San Joaquin diversions to W. Stanislaus ID	8.03	0%	106%
22	Moran Drain	0	0%	106%
24	Marshall Road Drain	0	0%	106%
59	Riparian 264	-1,921	0%	106%
12	Riparian diversion to catchment 843	-8,151	-0.1%	106%
20	Crows Landing-WS Div7	-8,417	-0.1%	106%
4	Riparian diversion to catchment 849	-11,371	-0.1%	106%
7	Riparian 852	-11,867	-0.1%	106%
33	Riparian 840	-16,417	-0.1%	106%
8	Riparian 854	-20,558	-0.1%	106%
43	Riparian diversions to Catchment 188	-30,807	-0.2%	106%
48	Riparian 291	-31,961	-0.2%	105%
56	Riparian diversions to catchment 188, part 2	-33,736	-0.2%	105%
18	Riparian diversions to catchment 955	-38,163	-0.2%	105%

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(Table 5 continued from the previous page)

River Point Number	Model Source Name	TN (kg)	% of Total Mass	Cumulative %
26	Riparian 960	-52,515	-0.3%	105%
42	Riparian 832	-53,437	-0.3%	104%
3	Riparian 836	-63,973	-0.4%	104%
44	Riparian diversions to catchments 188 & 200	-77,188	-0.5%	103%
17	Riparian 961	-78,136	-0.5%	103%
41	San Joaquin diversions to W. Stanislaus ID	-88,785	-1%	102%
50	El Solyo WD Pump Station	-127,360	-1%	102%
30	San Joaquin diversions to Patterson WD	-267,337	-2%	100%
	Total	**16,242,627**		

Table 6. Upstream sources of dissolved orthophosphate as phosphorus (PO_4-P) mass at Vernalis sorted by PO_4-P mass load from January 1, 2005 through September 30, 2007.

River Point Number	Model Source Name	PO_4-P (kg)	% of Total Mass	Cumulative %
45	Tuolumne River at SJR	161,148	23%	23%
57	Stanislaus River at SJR	106,907	15%	38%
2	San Joaquin at Lander Ave.	93,067	13%	51%
13	Merced River at Stevinson	90,857	13%	64%
32	Modesto WQCF Discharge	80,014	11%	75%
5	Salt Slough at San Joaquin River	45,502	6%	81%
49	Hospital / Ingram Creek	35,380	5%	86%
38	TID Lateral 2 Drain	34,613	5%	91%
10	Los Banos Creek at San Joaquin R.	28,144	4%	95%
19	TID Lateral 6 & 7 Spill	15,431	2%	97%
34	TID Lateral 3 (Westport) Drain	14,628	2%	100%
29	Salado Creek	12,515	2%	101%
46	MID Lateral 5 Spill	11,853	2%	103%
51	Subcatchment 188	11,234	2%	105%
25	TID Harding Drain	8,976	1%	106%
27	TID Lateral 5 (Carpenter) Drain	8,520	1%	107%
47	MID Lateral 4 Spill	7,793	1%	108%
15	Subcatchment 961	6,173	1%	109%
39	Subcatchment 832	4,451	1%	110%
35	Del Puerto Creek	3,387	0.5%	110%
31	Subcatchment 840	3,151	0.4%	111%
52	Subcatchment 291	2,933	0.4%	111%
40	Westley Wasteway	2,640	0.4%	111%
14	Subcatchment 955	2,363	0.3%	112%
1	Subcatchment 836	2,024	0.3%	112%
28	Subcatchment 960	1,442	0.2%	112%
21	Orestimba Creek near Crows Landing	1,090	0.2%	112%
11	Newman Wasteway	920	0.1%	112%
9	Subcatchment 854	653	0.1%	113%
6	Subcatchment 852	401	0.1%	113%
23	Spanish Land Grant Drain	187	0%	113%
16	CCID North/ SJR Drainage S	49.7	0%	113%
58	Subcatchment 264	49.1	0%	113%
55	El Solyo WD Pump Station	2.30	0%	113%
36	San Joaquin diversions to Patterson WD	2.09	0%	113%
54	W STANISLAUS ID deliveries from DMC	1.60	0%	113%
53	San Joaquin diversions to W. Stanislaus ID	0.731	0%	113%
37	PATTERSON WD deliveries from DMC	0.349	0%	113%
22	Moran Drain	0	0%	113%
24	Marshall Road Drain	0	0%	113%
59	Riparian 264	-189	0%	113%
20	Crows Landing-WS Div7	-536	-0.1%	112%
12	Riparian diversion to catchment 843	-796	-0.1%	112%
33	Riparian 840	-1,402	-0.2%	112%
4	Riparian diversion to catchment 849	-1,611	-0.2%	112%
7	Riparian 852	-1,670	-0.2%	112%
18	Riparian diversions to catchment 955	-2,285	-0.3%	111%
8	Riparian 854	-2,815	-0.4%	111%
48	Riparian 291	-2,873	-0.4%	111%
43	Riparian diversions to Catchment 188	-2,880	-0.4%	110%
56	Riparian diversions to catchment 188, part 2	-3,265	-0.5%	110%

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(Table 6 continued from the previous page)

River Point Number	Model Source Name	PO_4-P (kg)	% of Total Mass	Cumulative %
26	Riparian 960	-3,675	-1%	109%
17	Riparian 961	-4,790	-1%	109%
42	Riparian 832	-4,928	-1%	108%
44	Riparian diversions to catchments 188 & 200	-7,132	-1%	107%
41	San Joaquin diversions to W. Stanislaus ID	-7,994	-1%	106%
3	Riparian 836	-8,594	-1%	105%
50	El Solyo WD Pump Station	-11,907	-2%	103%
30	San Joaquin diversions to Patterson WD	-20,005	-3%	100%
	Total	**709,158**		

Table 7. Upstream sources of total phosphorus (TP) mass at Vernalis sorted by TP mass load from January 1, 2005 through September 30, 2007.

River Point Number	Model Source Name	TP (kg)	% of Total Mass	Cumulative %
2	San Joaquin at Lander Ave.	287,939	17%	17%
45	Tuolumne River at SJR	235,937	14%	31%
13	Merced River at Stevinson	187,065	11%	43%
5	Salt Slough at San Joaquin River	184,025	11%	54%
57	Stanislaus River at SJR	141,435	8%	62%
32	Modesto WQCF Discharge	111,149	7%	69%
10	Los Banos Creek at San Joaquin R.	103,238	6%	75%
19	TID Lateral 6 & 7 Spill	77,422	5%	80%
38	TID Lateral 2 Drain	65,388	4%	84%
49	Hospital / Ingram Creek	50,592	3%	87%
34	TID Lateral 3 (Westport) Drain	46,430	3%	89%
25	TID Harding Drain	42,053	3%	92%
27	TID Lateral 5 (Carpenter) Drain	37,948	2%	94%
29	Salado Creek	34,946	2%	96%
31	Subcatchment 840	34,576	2%	98%
46	MID Lateral 5 Spill	25,637	2%	100%
47	MID Lateral 4 Spill	16,497	1%	101%
51	Subcatchment 188	11,332	1%	102%
15	Subcatchment 961	10,815	1%	102%
39	Subcatchment 832	9,093	1%	103%
1	Subcatchment 836	8,922	1%	103%
35	Del Puerto Creek	7,457	0.4%	104%
21	Orestimba Creek near Crows Landing	6,502	0.4%	104%
11	Newman Wasteway	4,171	0.3%	104%
52	Subcatchment 291	4,128	0.2%	105%
9	Subcatchment 854	3,659	0.2%	105%
6	Subcatchment 852	3,420	0.2%	105%
14	Subcatchment 955	3,081	0.2%	105%
40	Westley Wasteway	2,748	0.2%	105%
28	Subcatchment 960	1,856	0.1%	106%
23	Spanish Land Grant Drain	743	0%	106%
16	CCID North/ SJR Drainage S	478	0%	106%
58	Subcatchment 264	49.2	0%	106%
36	San Joaquin diversions to Patterson WD	2.86	0%	106%
55	El Solyo WD Pump Station	2.42	0%	106%
54	W STANISLAUS ID deliveries from DMC	1.63	0%	106%
53	San Joaquin diversions to W. Stanislaus ID	0.770	0%	106%
37	PATTERSON WD deliveries from DMC	0.439	0%	106%
22	Moran Drain	0	0%	106%
24	Marshall Road Drain	0	0%	106%
59	Riparian 264	-197	0%	106%
20	Crows Landing-WS Div7	-634	0%	106%
12	Riparian diversion to catchment 843	-869	-0.1%	106%
33	Riparian 840	-1,467	-0.1%	105%
4	Riparian diversion to catchment 849	-1,671	-0.1%	105%
7	Riparian 852	-1,749	-0.1%	105%
18	Riparian diversions to catchment 955	-2,433	-0.1%	105%
8	Riparian 854	-2,879	-0.2%	105%
48	Riparian 291	-2,991	-0.2%	105%
43	Riparian diversions to Catchment 188	-3,030	-0.2%	105%
56	Riparian diversions to catchment 188, part 2	-3,430	-0.2%	104%

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(Table 7 continued from the previous page)

River Point Number	Model Source Name	TP (kg)	% of Total Mass	Cumulative %
26	Riparian 960	-3,896	-0.2%	104%
17	Riparian 961	-5,044	-0.3%	104%
42	Riparian 832	-5,126	-0.3%	103%
44	Riparian diversions to catchments 188 & 200	-7,474	-0.4%	103%
41	San Joaquin diversions to W. Stanislaus ID	-8,380	-1%	103%
3	Riparian 836	-8,701	-1%	102%
50	El Solyo WD Pump Station	-12,467	-1%	101%
30	San Joaquin diversions to Patterson WD	-21,190	-1%	100%
	Total	**1,667,112**		

Table 8. Upstream sources of dissolved organic carbon (DOC) at Vernalis sorted by DOC mass load from January 1, 2005 through September 30, 2007.

River Point Number	Model Source Name	DOC (kg)	% of Total Mass	Cumulative %
2	San Joaquin at Lander Ave.	13,259,244	24%	24%
45	Tuolumne River at SJR	11,430,367	21%	45%
57	Stanislaus River at SJR	7,546,678	14%	59%
13	Merced River at Stevinson	7,025,985	13%	71%
10	Los Banos Creek at San Joaquin R.	3,700,218	7%	78%
5	Salt Slough at San Joaquin River	3,591,254	7%	85%
38	TID Lateral 2 Drain	1,478,353	3%	87%
19	TID Lateral 6 & 7 Spill	1,287,219	2%	90%
49	Hospital / Ingram Creek	1,141,549	2%	92%
32	Modesto WQCF Discharge	966,216	2%	94%
34	TID Lateral 3 (Westport) Drain	903,857	2%	95%
25	TID Harding Drain	758,510	1%	97%
27	TID Lateral 5 (Carpenter) Drain	705,473	1%	98%
29	Salado Creek	615,357	1%	99%
35	Del Puerto Creek	594,632	1%	100%
46	MID Lateral 5 Spill	530,798	1%	101%
21	Orestimba Creek near Crows Landing	482,515	1%	102%
47	MID Lateral 4 Spill	354,626	1%	103%
51	Subcatchment 188	199,017	0.4%	103%
15	Subcatchment 961	142,618	0.3%	103%
11	Newman Wasteway	115,988	0.2%	103%
39	Subcatchment 832	97,946	0.2%	104%
52	Subcatchment 291	64,292	0.1%	104%
31	Subcatchment 840	62,329	0.1%	104%
40	Westley Wasteway	47,030	0.1%	104%
14	Subcatchment 955	45,747	0.1%	104%
9	Subcatchment 854	36,268	0.1%	104%
28	Subcatchment 960	35,793	0.1%	104%
23	Spanish Land Grant Drain	28,522	0.1%	104%
6	Subcatchment 852	21,765	0%	104%
1	Subcatchment 836	15,291	0%	104%
16	CCID North/ SJR Drainage S	7,735	0%	104%
58	Subcatchment 264	7,412	0%	104%
36	San Joaquin diversions to Patterson WD	73.5	0%	104%
55	El Solyo WD Pump Station	53.2	0%	104%
54	W STANISLAUS ID deliveries from DMC	32.1	0%	104%
53	San Joaquin diversions to W. Stanislaus ID	17.4	0%	104%
37	PATTERSON WD deliveries from DMC	8.08	0%	104%
22	Moran Drain	0	0%	104%
24	Marshall Road Drain	0	0%	104%
59	Riparian 264	-4,925	0%	104%
20	Crows Landing-WS Div7	-17,668	0%	104%
12	Riparian diversion to catchment 843	-27,245	-0.1%	104%
4	Riparian diversion to catchment 849	-30,806	-0.1%	104%
33	Riparian 840	-34,410	-0.1%	104%
7	Riparian 852	-47,070	-0.1%	104%
43	Riparian diversions to Catchment 188	-66,639	-0.1%	104%
48	Riparian 291	-70,542	-0.1%	104%
56	Riparian diversions to catchment 188, part 2	-74,843	-0.1%	104%
18	Riparian diversions to catchment 955	-79,688	-0.1%	103%
8	Riparian 854	-80,216	-0.1%	103%

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(Table 8 continued from the previous page)

River Point Number	Model Source Name	DOC (kg)	% of Total Mass	Cumulative %
26	Riparian 960	-111,900	-0.2%	103%
42	Riparian 832	-117,515	-0.2%	103%
44	Riparian diversions to catchments 188 & 200	-165,116	-0.3%	103%
17	Riparian 961	-169,911	-0.3%	102%
3	Riparian 836	-188,630	-0.3%	102%
41	San Joaquin diversions to W. Stanislaus ID	-189,458	-0.3%	102%
50	El Solyo WD Pump Station	-280,262	-1%	101%
30	San Joaquin diversions to Patterson WD	-586,763	-1%	100%
	Total	**54,957,181**		

Table 9. Upstream sources of carbonaceous biochemical oxygen demand (CBOD) at Vernalis sorted by CBOD mass load from January 1, 2005 through September 30, 2007.

River Point Number	Model Source Name	CBOD (kg)	% of Total Mass	Cumulative %
45	Tuolumne River at SJR	6,317,240	29%	29%
2	San Joaquin at Lander Ave.	6,216,043	28%	57%
57	Stanislaus River at SJR	2,951,504	13%	70%
13	Merced River at Stevinson	2,789,617	13%	83%
10	Los Banos Creek at San Joaquin R.	1,946,402	9%	91%
5	Salt Slough at San Joaquin River	1,124,182	5%	96%
32	Modesto WQCF Discharge	574,430	3%	99%
11	Newman Wasteway	220,293	1%	100%
31	Subcatchment 840	174,427	1%	101%
21	Orestimba Creek near Crows Landing	126,043	1%	101%
49	Hospital / Ingram Creek	103,060	0.5%	102%
35	Del Puerto Creek	102,218	0.5%	102%
29	Salado Creek	74,398	0.3%	103%
19	TID Lateral 6 & 7 Spill	59,832	0.3%	103%
38	TID Lateral 2 Drain	44,899	0.2%	103%
34	TID Lateral 3 (Westport) Drain	41,098	0.2%	103%
25	TID Harding Drain	36,607	0.2%	103%
27	TID Lateral 5 (Carpenter) Drain	34,170	0.2%	104%
1	Subcatchment 836	33,648	0.2%	104%
46	MID Lateral 5 Spill	25,110	0.1%	104%
9	Subcatchment 854	22,078	0.1%	104%
23	Spanish Land Grant Drain	18,921	0.1%	104%
6	Subcatchment 852	17,718	0.1%	104%
47	MID Lateral 4 Spill	15,599	0.1%	104%
16	CCID North/ SJR Drainage S	14,414	0.1%	104%
15	Subcatchment 961	9,160	0%	104%
39	Subcatchment 832	8,753	0%	104%
51	Subcatchment 188	8,417	0%	104%
52	Subcatchment 291	4,520	0%	104%
28	Subcatchment 960	1,973	0%	104%
40	Westley Wasteway	1,876	0%	104%
14	Subcatchment 955	1,815	0%	104%
58	Subcatchment 264	1,405	0%	104%
36	San Joaquin diversions to Patterson WD	31.6	0%	104%
55	El Solyo WD Pump Station	19.7	0%	104%
53	San Joaquin diversions to W. Stanislaus ID	6.06	0%	104%
54	W STANISLAUS ID deliveries from DMC	5.11	0%	104%
37	PATTERSON WD deliveries from DMC	1.28	0%	104%
22	Moran Drain	0	0%	104%
24	Marshall Road Drain	0	0%	104%
59	Riparian 264	-1,749	0%	104%
20	Crows Landing-WS Div7	-9,057	0%	104%
33	Riparian 840	-14,336	-0.1%	104%
12	Riparian diversion to catchment 843	-15,667	-0.1%	104%
4	Riparian diversion to catchment 849	-16,825	-0.1%	104%
7	Riparian 852	-19,941	-0.1%	104%
43	Riparian diversions to Catchment 188	-23,897	-0.1%	104%
48	Riparian 291	-25,757	-0.1%	104%
56	Riparian diversions to catchment 188, part 2	-26,808	-0.1%	104%
8	Riparian 854	-33,968	-0.2%	104%
42	Riparian 832	-41,763	-0.2%	103%

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(Table 9 continued from the previous page)

River Point Number	Model Source Name	CBOD (kg)	% of Total Mass	Cumulative %
18	Riparian diversions to catchment 955	-44,645	-0.2%	103%
26	Riparian 960	-50,636	-0.2%	103%
44	Riparian diversions to catchments 188 & 200	-59,161	-0.3%	103%
41	San Joaquin diversions to W. Stanislaus ID	-68,702	-0.3%	102%
17	Riparian 961	-90,254	-0.4%	102%
3	Riparian 836	-101,118	-0.5%	102%
50	El Solyo WD Pump Station	-103,692	-0.5%	101%
30	San Joaquin diversions to Patterson WD	-243,308	-1%	100%
	Total	**22,130,653**		

Table 10. Upstream sources of total dissolved solids (TDS) at Vernalis sorted by TDS mass load from January 1, 2005 through September 30, 2007.

River Point Number	Model Source Name	TDS (kg)	% of Total Mass	Cumulative %
10	Los Banos Creek at San Joaquin R.	654,164,375	24%	24%
5	Salt Slough at San Joaquin River	411,292,015	15%	39%
2	San Joaquin at Lander Ave.	332,712,697	12%	51%
45	Tuolumne River at SJR	295,108,565	11%	61%
57	Stanislaus River at SJR	203,027,126	7%	69%
49	Hospital / Ingram Creek	139,054,309	5%	74%
13	Merced River at Stevinson	127,618,173	5%	78%
11	Newman Wasteway	117,613,637	4%	83%
19	TID Lateral 6 & 7 Spill	100,132,170	4%	86%
29	Salado Creek	86,864,284	3%	89%
38	TID Lateral 2 Drain	72,849,743	3%	92%
25	TID Harding Drain	62,607,756	2%	94%
34	TID Lateral 3 (Westport) Drain	61,695,008	2%	97%
27	TID Lateral 5 (Carpenter) Drain	56,582,915	2%	99%
51	Subcatchment 188	48,427,852	2%	100%
1	Subcatchment 836	41,190,869	1%	102%
46	MID Lateral 5 Spill	32,859,221	1%	103%
23	Spanish Land Grant Drain	26,445,944	1%	104%
15	Subcatchment 961	25,484,079	1%	105%
47	MID Lateral 4 Spill	23,220,576	1%	106%
16	CCID North/ SJR Drainage S	20,148,947	1%	106%
39	Subcatchment 832	19,393,362	1%	107%
31	Subcatchment 840	18,888,615	1%	108%
35	Del Puerto Creek	16,900,358	1%	108%
21	Orestimba Creek near Crows Landing	16,058,759	1%	109%
32	Modesto WQCF Discharge	14,712,548	1%	110%
9	Subcatchment 854	12,322,591	0.4%	110%
14	Subcatchment 955	12,200,799	0.4%	110%
6	Subcatchment 852	8,392,344	0.3%	111%
52	Subcatchment 291	8,181,779	0.3%	111%
40	Westley Wasteway	5,295,934	0.2%	111%
28	Subcatchment 960	3,887,480	0.1%	111%
58	Subcatchment 264	557,672	0%	111%
36	San Joaquin diversions to Patterson WD	9,058	0%	111%
55	El Solyo WD Pump Station	5,135	0%	111%
54	W STANISLAUS ID deliveries from DMC	2,476	0%	111%
53	San Joaquin diversions to W. Stanislaus ID	1,993	0%	111%
37	PATTERSON WD deliveries from DMC	557	0%	111%
22	Moran Drain	0	0%	111%
24	Marshall Road Drain	0	0%	111%
59	Riparian 264	-420,406	0%	111%
20	Crows Landing-WS Div7	-2,694,029	-0.1%	111%
33	Riparian 840	-4,485,231	-0.2%	111%
12	Riparian diversion to catchment 843	-5,736,398	-0.2%	111%
48	Riparian 291	-6,901,207	-0.3%	111%
7	Riparian 852	-7,185,328	-0.3%	110%
4	Riparian diversion to catchment 849	-7,291,447	-0.3%	110%
56	Riparian diversions to catchment 188, part 2	-7,680,935	-0.3%	110%
43	Riparian diversions to Catchment 188	-7,974,585	-0.3%	110%
18	Riparian diversions to catchment 955	-12,016,642	-0.4%	109%
8	Riparian 854	-12,288,780	-0.4%	109%

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(Table 10 continued from the previous page)

River Point Number	Model Source Name	TDS (kg)	% of Total Mass	Cumulative %
42	Riparian 832	-13,751,726	-0.5%	108%
26	Riparian 960	-15,447,438	-1%	108%
44	Riparian diversions to catchments 188 & 200	-18,975,974	-1%	107%
41	San Joaquin diversions to W. Stanislaus ID	-22,349,993	-1%	106%
17	Riparian 961	-24,410,493	-1%	105%
50	El Solyo WD Pump Station	-27,280,125	-1%	104%
3	Riparian 836	-38,944,958	-1%	103%
30	San Joaquin diversions to Patterson WD	-79,898,278	-3%	100%
	Total	**2,760,177,751**		

Table 11. Upstream sources of total phytoplankton as chlorophyll-a (chl) at Vernalis sorted by phytoplankton mass load from January 1, 2005 through September 30, 2007.

River Point Number	Model Source Name	Total Phytoplankton (kg chl)	% of Total Mass	Cumulative %
2	San Joaquin at Lander Ave.	121,688	68%	68%
10	Los Banos Creek at San Joaquin R.	20,112	11%	79%
45	Tuolumne River at SJR	18,228	10%	89%
13	Merced River at Stevinson	15,458	9%	98%
57	Stanislaus River at SJR	11,388	6%	104%
38	TID Lateral 2 Drain	855	0.5%	105%
5	Salt Slough at San Joaquin River	510	0.3%	105%
11	Newman Wasteway	41.0	0%	105%
21	Orestimba Creek near Crows Landing	32.2	0%	105%
19	TID Lateral 6 & 7 Spill	25.8	0%	105%
49	Hospital / Ingram Creek	15.3	0%	105%
34	TID Lateral 3 (Westport) Drain	14.0	0%	105%
25	TID Harding Drain	13.6	0%	105%
27	TID Lateral 5 (Carpenter) Drain	12.8	0%	105%
29	Salado Creek	12.6	0%	105%
46	MID Lateral 5 Spill	7.58	0%	105%
35	Del Puerto Creek	5.96	0%	105%
23	Spanish Land Grant Drain	5.95	0%	105%
1	Subcatchment 836	5.32	0%	105%
47	MID Lateral 4 Spill	4.55	0%	105%
32	Modesto WQCF Discharge	4.17	0%	105%
31	Subcatchment 840	3.69	0%	105%
15	Subcatchment 961	1.72	0%	105%
39	Subcatchment 832	1.38	0%	105%
52	Subcatchment 291	0.719	0%	105%
40	Westley Wasteway	0.598	0%	105%
9	Subcatchment 854	0.593	0%	105%
36	San Joaquin diversions to Patterson WD	0.450	0%	105%
6	Subcatchment 852	0.407	0%	105%
55	El Solyo WD Pump Station	0.237	0%	105%
51	Subcatchment 188	0.101	0%	105%
53	San Joaquin diversions to W. Stanislaus ID	0.0777	0%	105%
16	CCID North/ SJR Drainage S	0.0444	0%	105%
54	W STANISLAUS ID deliveries from DMC	0.0338	0%	105%
37	PATTERSON WD deliveries from DMC	0.0119	0%	105%
28	Subcatchment 960	0	0%	105%
58	Subcatchment 264	0	0%	105%
14	Subcatchment 955	0	0%	105%
22	Moran Drain	0	0%	105%
24	Marshall Road Drain	0	0%	105%
59	Riparian 264	-16.4	0%	105%
7	Riparian 852	-109	-0.1%	105%
20	Crows Landing-WS Div7	-129	-0.1%	105%
4	Riparian diversion to catchment 849	-139	-0.1%	105%
8	Riparian 854	-167	-0.1%	105%
33	Riparian 840	-179	-0.1%	105%
12	Riparian diversion to catchment 843	-214	-0.1%	104%
48	Riparian 291	-265	-0.1%	104%
56	Riparian diversions to catchment 188, part 2	-321	-0.2%	104%
43	Riparian diversions to Catchment 188	-335	-0.2%	104%
18	Riparian diversions to catchment 955	-405	-0.2%	104%

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(Table 11 continued from the previous page)

River Point Number	Model Source Name	Total Phytoplankton (kg chl)	% of Total Mass	Cumulative %
3	Riparian 836	-411	-0.2%	103%
42	Riparian 832	-439	-0.2%	103%
26	Riparian 960	-442	-0.2%	103%
17	Riparian 961	-578	-0.3%	103%
44	Riparian diversions to catchments 188 & 200	-712	-0.4%	102%
41	San Joaquin diversions to W. Stanislaus ID	-798	-0.4%	102%
50	El Solyo WD Pump Station	-1,095	-1%	101%
30	San Joaquin diversions to Patterson WD	-2,154	-1%	100%
	Total	**179,546**		

Table 12. Comparison of WARMF 2012 Gowdy Output loads at Vernalis and boundary inflow loads for the Stanislaus, Tuolumne, and Merced Rivers. Boundary inflow file mass loads for total phytoplankton as chlorophyll-a (chl) are for diatoms only.

	Source Name	NO_3-N (kg)	TAN (kg)	PO_4-P (kg)	DOC (kg)	CBOD (kg)	Total Phytoplankton (kg chl)
Gowdy Output	Stanislaus River	692,127	196,977	106,907	7,546,678	2,951,504	11,388
	Tuolumne River	1,855,412	254,467	161,148	11,430,367	6,317,240	18,228
	Merced River	1,959,143	96,858	90,857	7,025,985	2,789,617	15,458
Boundary Inflow Files	Stanislaus River	896,026	244,549	173,141	10,540,325	4,310,621	15,415
	Tuolumne River	1,810,510	304,350	198,260	11,459,771	6,184,765	15,195
	Merced River	1,862,465	233,299	117,130	7,360,824	2,907,409	8,660

Table 13. Comparison of WARMF 2012 Gowdy Output masses with masses calculated from the WARMF 2008 load removal analysis from January 1, 2005 through September 30, 2007. Mass from the load removal analysis for each tributary was calculated by subtracting the mass at Vernalis resulting from the removal of tributaries from the total mass at Vernalis.

		NO_3-N (kg)		TAN (kg)		TN (kg)		PO_4-P (kg)		TP (kg)	
Model Version	**Model Source Name**	**Mass Load**	**% of Total**	**Mass Load**	**% of Total**	**Mass Load**	**% of Total**	**Mass Load**	**% of Total**	**Mass Load**	**% of Total**
2012	Tuolumne River	1,855,412	24%	254,467	23%	3,161,356	19%	161,148	23%	235,937	14%
	Stanislaus River	692,127	9%	196,977	18%	1,561,827	10%	106,907	15%	141,435	8%
	San Joaquin at Lander Ave.	641,873	8%	65,834	6%	2,515,338	15%	93,067	13%	287,939	17%
	Merced River	1,959,143	25%	96,858	9%	2,759,603	17%	90,857	13%	187,065	11%
	Salt Slough	356,982	5%	11,921	1%	791,190	5%	45,502	6%	184,025	11%
	Hospital / Ingram Creek	181,828	2%	64,224	6%	365,709	2%	35,380	5%	50,592	3%
	Los Banos Creek & Mud Slough	534,104	7%	17,487	2%	1,033,915	6%	28,144	4%	103,238	6%
	TID Lateral 3 (Westport) Drain	139,833	2%	53,543	5%	351,841	2%	14,628	2%	46,430	3%
	TID Harding Drain	124,210	2%	39,922	4%	378,204	2%	8,976	1%	42,053	3%
	Del Puerto Creek	23,024	0%	24,994	2%	121,004	1%	3,387	0%	7,457	0%
	Orestimba Creek near Crows Landing	66,632	1%	1,034	0%	120,181	1%	1,090	0%	6,502	0%
	Other	1,315,803	17%	257,669	24%	3,082,459	19%	120,072	17%	374,439	22%
	Total Mass at Vernalis	**7,890,971**		**1,084,928**		**16,242,627**		**709,158**		**1,667,112**	
2008	Tuolumne River	1,897,004	17%	21,893	2%	3,032,087	16%	47,590	4%	214,052	8%
	Stanislaus River	529,498	5%	28,911	3%	1,224,329	6%	37,677	3%	132,193	5%
	San Joaquin at Lander Ave.	463,076	4%	-18,624	-2%	1,766,977	9%	77,184	6%	255,465	10%
	Merced River	1,452,977	13%	57,585	5%	2,330,053	12%	26,750	2%	145,899	5%
	Salt Slough	671,170	6%	-34,028	-3%	1,029,573	5%	28,566	2%	117,629	4%
	Hospital Creek	17,547	0%	22,933	2%	124,401	1%	12,776	1%	38,481	1%
	Ingram Creek	163,046	1%	43,819	4%	341,545	2%	-472	0%	9,012	0%
	Mud Slough	1,213,488	11%	-28,853	-3%	1,557,736	8%	16,076	1%	69,997	3%
	Los Banos Creek	65,552	1%	-93.7	0%	189,807	1%	23,767	2%	61,026	2%
	TID Lateral 3 (Westport) Drain	468,153	4%	1,897	0%	487,344	3%	6,561	0%	13,112	0%
	TID Harding Drain	769,665	7%	5,453	0%	824,761	4%	96,360	7%	187,260	7%
	Del Puerto Creek	19,255	0%	9,591	1%	56,988	0%	534	0%	2,283	0%
	Orestimba Creek	137,728	1%	4,643	0%	225,332	1%	3,418	0%	26,383	1%
	Other	3,513,633	31%	1,037,475	90%	6,258,556	32%	939,722	71%	1,397,399	52%
	Total Mass at Vernalis	**11,381,791**		**1,152,600**		**19,449,488**		**1,316,508**		**2,670,190**	

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(Table 13 continued from the previous page)

		DOC (kg)		CBOD (kg)		TDS (kg)		Total Phytoplankton (kg chl)	
Model Version	**Source Name**	**Mass Load**	**% of Total**	**Mass Load**	**% of Total**	**Mass Load**	**% of Total**	**Mass Load**	**% of Total**
2012	Tuolumne River	11,430,367	21%	6,317,240	29%	295,108,565	11%	18,228	10%
	Stanislaus River	7,546,678	14%	2,951,504	13%	203,027,126	7%	11,388	6%
	San Joaquin at Lander Ave.	13,259,244	24%	6,216,043	28%	332,712,697	12%	121,688	68%
	Merced River	7,025,985	13%	2,789,617	13%	127,618,173	5%	15,458	9%
	Salt Slough	3,591,254	7%	1,124,182	5%	411,292,015	15%	510	0%
	Hospital / Ingram Creek	1,141,549	2%	103,060	0%	139,054,309	5%	15.3	0%
	Los Banos Creek & Mud Slough	3,700,218	7%	1,946,402	9%	654,164,375	24%	20,112	11%
	TID Lateral 3 (Westport) Drain	903,857	2%	41,098	0%	61,695,008	2%	14.0	0%
	TID Harding Drain	758,510	1%	36,607	0%	62,607,756	2%	13.6	0%
	Del Puerto Creek	594,632	1%	102,218	0%	16,900,358	1%	5.96	0%
	Orestimba Creek near Crows Landing	482,515	1%	126,043	1%	16,058,759	1%	32.2	0%
	Other	4,522,371	8%	376,639	2%	439,938,608	16%	-7,921	-4%
	Total Mass at Vernalis	**54,957,181**		**22,130,653**		**2,760,177,751**		**179,546**	
2008	Tuolumne River	11,117,426	21%	11,344,290	34%	294,547,511	10%	16,656	7%
	Stanislaus River	6,515,617	12%	2,482,005	7%	152,176,386	5%	9,900	4%
	San Joaquin at Lander Ave.	12,015,592	23%	6,027,505	18%	275,668,728	10%	85,600	37%
	Merced River	6,763,899	13%	3,376,968	10%	151,783,124	5%	18,338	8%
	Salt Slough	2,476,740	5%	1,435,925	4%	422,835,225	15%	51,120	22%
	Hospital Creek	82,020	0%	135,978	0%	4,248,587	0%	362	0%
	Ingram Creek	118,736	0%	63,321	0%	23,159,298	1%	614	0%
	Mud Slough	2,833,736	5%	1,968,219	6%	549,375,566	19%	46,689	20%
	Los Banos Creek	842,720	2%	607,799	2%	90,199,967	3%	12,890	6%
	TID Lateral 3 (Westport) Drain	140,930	0%	91,528	0%	19,850,598	1%	566	0%
	TID Harding Drain	357,381	1%	223,321	1%	48,886,800	2%	2,112	1%
	Del Puerto Creek	62,018	0%	37,797	0%	5,923,163	0%	273	0%
	Orestimba Creek	425,729	1%	192,540	1%	27,399,281	1%	2,370	1%
	Other	8,854,454	17%	5,457,177	16%	763,456,805	27%	-18,903	-8%
	Total Mass at Vernalis	**52,606,997**		**33,444,374**		**2,829,511,040**		**228,585**	

Table 14. Comparison of WARMF 2012 Gowdy Output masses with masses calculated from the WARMF 2008 load removal analysis from January 1, 2005 through September 30, 2007, with loads expressed as the WARMF 2012 loads minus the WARMF 2008 loads and percent differences expressed with respect to the WARMF 2008 loads. Masses from the load removal analysis for each tributary were calculated by subtracting the mass at Vernalis resulting from the removal of tributary from the total mass at Vernalis.

	NO_3-N (kg)		TAN (kg)		TN (kg)		PO_4-P (kg)		TP (kg)	
Source Name	**Mass Load**	**% Diff.**	**Mass Load**	**% Diff.**	**Mass Load**	**% Diff.**	**Mass Load**	**% Diff.**	**Mass Load**	**% Diff.**
Tuolumne River	-41,592	-2%	232,574	1,062%	129,270	4%	113,559	239%	21,885	10%
Stanislaus River	162,629	31%	168,066	581%	337,498	28%	69,230	184%	9,242	7%
San Joaquin at Lander Ave.	178,797	39%	84,458	-453%	748,360	42%	15,883	21%	32,474	13%
Merced River	506,166	35%	39,273	68%	429,550	18%	64,107	240%	41,166	28%
Salt Slough	-314,188	-47%	45,949	-135%	-238,383	-23%	16,935	59%	66,396	56%
Hospital / Ingram Creek	1,235	1%	-2,528	-4%	-100,236	-22%	23,077	188%	3,099	7%
Los Banos Creek & Mud Slough	-744,936	-58%	46,434	-160%	-713,629	-41%	-11,698	-29%	-27,785	-21%
TID Lateral 3 (Westport) Drain	-328,319	-70%	51,645	2,722%	-135,503	-28%	8,067	123%	33,319	254%
TID Harding Drain	-645,455	-84%	34,469	632%	-446,557	-54%	-87,384	-91%	-145,207	-78%
Del Puerto Creek	3,769	20%	15,403	161%	64,016	112%	2,853	534%	5,175	227%
Orestimba Creek near Crows Landing	-71,096	-52%	-3,610	-78%	-105,151	-47%	-2,328	-68%	-19,881	-75%
Other	-2,197,830	-63%	-779,806	-75%	-3,176,096	-51%	-819,650	-87%	-1,022,960	-73%
Total Mass at Vernalis	**-3,490,821**	**-31%**	**-67,673**	**-6%**	**-3,206,861**	**-16%**	**-607,350**	**-46%**	**-1,003,078**	**-38%**

(continued on the next page)

(Table 14 continued from the previous page)

	DOC (kg)		CBOD (kg)		TDS (kg)		Total Phytoplankton (kg chl)	
Source Name	**Mass Load**	**% Diff.**	**Mass Load**	**% Diff.**	**Mass Load**	**% Diff.**	**Mass Load**	**% Diff.**
Tuolumne River	312,942	3%	-5,027,050	-44%	561,055	0%	1,573	9%
Stanislaus River	1,031,062	16%	469,499	19%	50,850,740	33%	1,488	15%
San Joaquin at Lander Ave.	1,243,652	10%	188,538	3%	57,043,970	21%	36,088	42%
Merced River	262,087	4%	-587,352	-17%	-24,164,951	-16%	-2,880	-16%
Salt Slough	1,114,514	45%	-311,743	-22%	-11,543,210	-3%	-50,610	-99%
Hospital / Ingram Creek	940,792	469%	-96,239	-48%	111,646,423	407%	-960	-98%
Los Banos Creek & Mud Slough	23,762	1%	-629,616	-24%	14,588,842	2%	-39,466	-66%
TID Lateral 3 (Westport) Drain	762,927	541%	-50,430	-55%	41,844,410	211%	-552	-98%
TID Harding Drain	401,129	112%	-186,714	-84%	13,720,956	28%	-2,098	-99%
Del Puerto Creek	532,614	859%	64,421	170%	10,977,195	185%	-267	-98%
Orestimba Creek near Crows Landing	56,785	13%	-66,498	-35%	-11,340,523	-41%	-2,338	-99%
Other	-4,332,082	-49%	-5,080,538	-93%	-323,518,196	-42%	10,982	-58%
Total Load	**2,350,185**	**4%**	**-11,313,721**	**-34%**	**-69,333,289**	**-2%**	**-49,039**	**-21%**

Figure 1. Overview of updates to the WARMF model domain between 2008 and 2012 from individual projects (Herr, Chen, and van Werkhoven 2008; Larry Walker Associates, et al. 2010; USBR 2012a; USBR2012c; Systech 2011; Systech 2013).

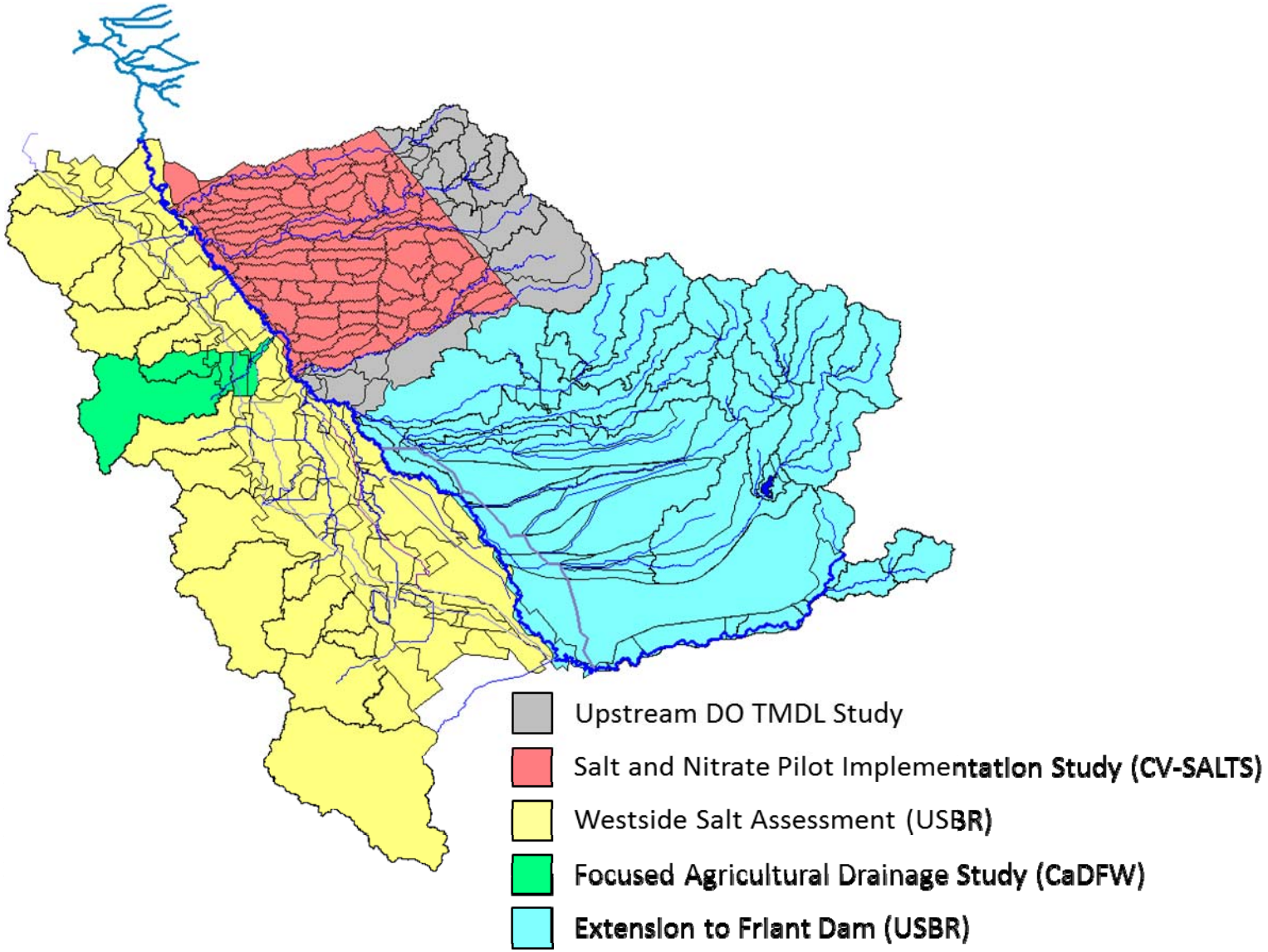

Figure 2. Overview of the WARMF 2012 model domain, which consists of the San Joaquin River and its tributaries from the Millerton Lake Tailwater to Old River. Catchments (highlighted in yellow) downstream of the Millerton Lake Tailwater on the SJR are included in the model domain; gray catchments are excluded. The Gowdy Output analysis was applied to sources that discharge into the San Joaquin River near Stevinson to Vernalis (highlighted in red).

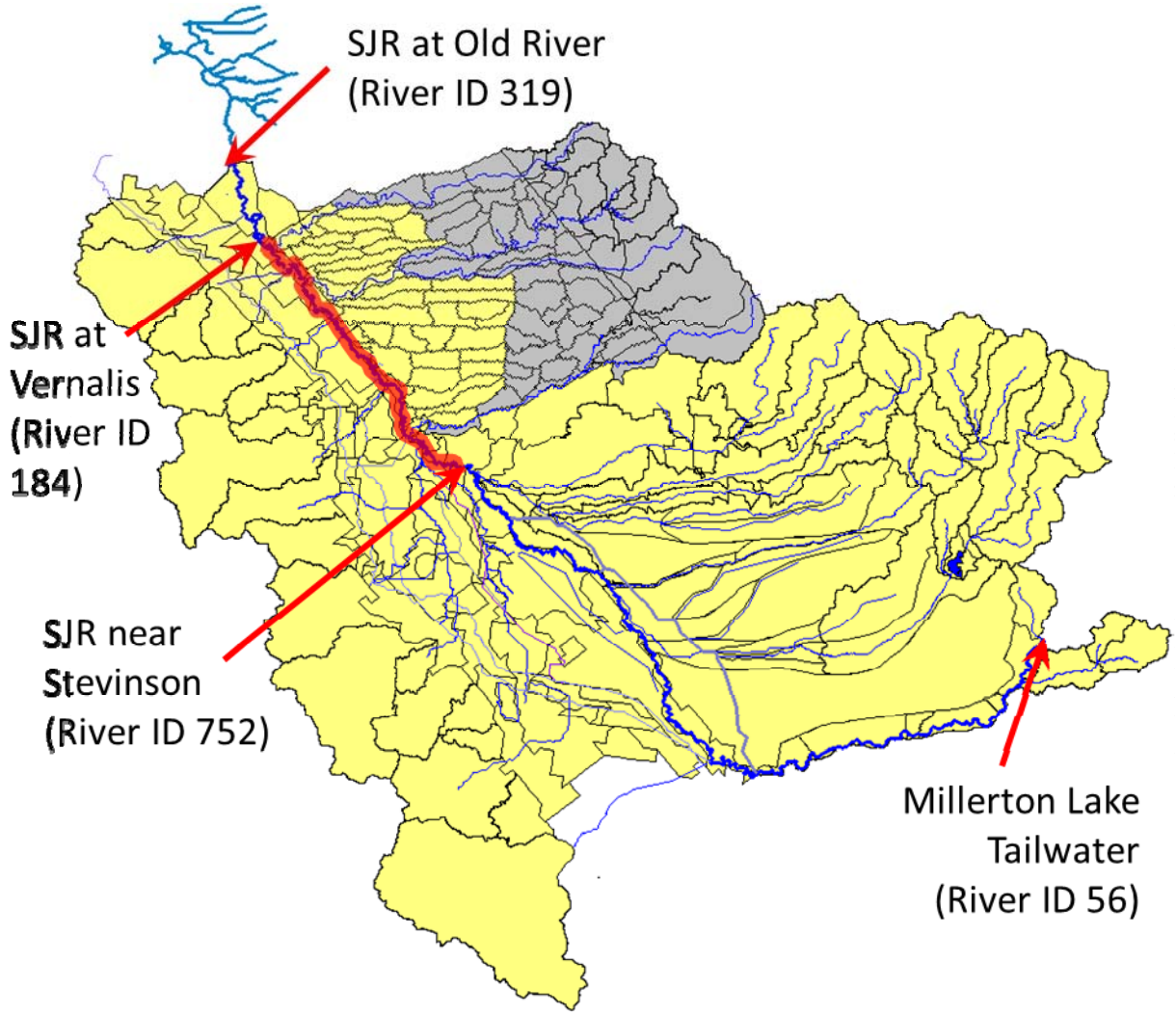

Figure 3. Map of Gowdy Output river points. Each point corresponds to a catchment, diversion, or river discharging into or drawing water from the San Joaquin River (SJR), represented with a red square for catchments, a green circle for diversions, and a blue hexagon for rivers. The numbers correspond to river points listed in Table A.